MODELING THE SANTA BARBARA CHANNEL USING REALISTIC OPEN BOUNDARY CONDITIONS AND WINDS

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LONG-TERM GOALS

To numerically model basic small-scale coastal phenomena using ultra-high resolution on advanced computers for ultimate development of a nowcast/forecast system.

OBJECTIVES

The main objective is realistic modeling of the Santa Barbara Channel (SBC) leading to nowcast/forecast capability. This goal requires accurate winds and open boundary conditions, and a model having: adequate representation of the surface mixed layer dynamics; good accuracy for the dominant Coriolis and internal wave propagation terms; realistically small numerical dissipation and dispersion; and a good representation of the bottom boundary layer especially in shallow coastal regions.

APPROACH

To achieve the above goals, the following approach was used: a) nesting of the high resolution (one minute) DieCAST SBC model within our California Current (CC) model in collaboration with the Naval Postgraduate School (NPS); b) implementation of the recent nesting technology under advice from the Los Alamos National Laboratory Numerical Analysis and Parallel Computing Team Scientific Computing Group (CIC0-19; William Henshaw, Jeff Saltzman, David Brown, et al, personal communication); and c) use of surface winds from the COADS database for both the CC and SBC models augmented by coastal headland jets. The emphasis was to use realistic wind forcing with an existing mixing approach, and to implement a good nesting approach which provides good open boundary conditions for a high resolution SBC model.

WORK COMPLETED

Nesting of the SBC model within the CC model.

Annual cycle studies for the CC region.

Preliminary nested SBC results regards local wind sensitivity.

RESULTS

A modified Arakawa "a" grid SBC version of DieCAST has been nested within the CC model developed in collaboration with NPS (Dr. Bob Haney and Bob Hale). Even with no sponge layers,

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the open SBC boundaries have little noise. The nested SBC results (1/60 deg resolution) are consistent with the lower resolution (1/12 deg) CC model results in the same region, yet rich in internal smaller-scale features than resolved by the coarser CC model.

Observed coastal mesoscale (40 km wide, 3-10 dynes/cm-cm) wind forcing jets have been added to our CC model. These elongated jets stretch southward from main coastal headlands. Their monthly mean surface stress is ~3 dynes/cm-cm along the jet centerlines. Synoptic events often give O(10) dynes/cm-cm.

Results using Hellerman summer winds enhanced by the 3 dyne/cm-cm summer mean forcing show significant differences compared to results using only Hellerman winds (Bob Hale, personal communication). It thus may be necessary for coastal models to respond accurately to such small (40 km) scale wind jets in order to get realistic near-shore flow results. DieCAST responds strongly using 1/12 deg resolution. Later, time permitting, we will include synoptic events.

The SBC has near zero mean flow, because of a near balance between a local-wind-forced surface Ekman layer flow and its associated upwelling (northern SBC) and downwelling (southern SBC) distribution, and external effects from the Davidson Current and the CC system. Fluctuations away from this near balance lead to the four main SBC regimes.

To explore the effects of this balance, we ran two simulations of our high resolution (1 minute) SBC model under summer conditions. Open boundary conditions were derived from our 5 minute resolution CC model. A time-dependent Davidson Current was specified at the southern open boundary of the CC model. Initially it is concentrated near shore, later away from shore.

The only difference between the two runs is the local wind forcing. Case 1 uses pure Hellerman summer winds. Case 2 uses Hellerman winds, modified by an idealized sub-Hellerman "mountain shadow" reduced wind region in the northern SBC. This wind modification was constructed by solving a Poisson equation for the wind stress with zero wind at shore and specified Hellerman wind stress about 10 km off-shore. Figure 1 shows the modified Hellerman (with mountain shadow effect) used for Case 2. The contours are wind magnitude. Figures 2 - 3 compare the two cases at days 30 and 60. In both cases a strong cyclonic eddy quickly develops and dominates the deep central SBC as the water column stretches vertically in passing over the deep central basin. The implied barotropic convergence quickly leads to a strong central basin cyclonic flow. Such convergence occurs whether the water comes from the east or west, consistent with observed central basin generally cyclonic flow. However, the eastward flow forced by upwelling favorable north rim Hellerman winds (Case 1) constrains the central basin cyclonic eddy to have less latitudinal extent than when "mountain shadow" modified winds are used (Case 2). The Case 1 central basin eddy actually breaks into two cyclonic centers at day 15, before forming a smaller central basin cyclone (figure 3). The mean westward flow in Case 2 leads to westward propagation. Advection has more important effect on its westward propagation than Rossby wave dynamics.

Day 60 density fields (not shown) indicate that in Case 2, warm water from the east propagates around the north side of the cyclone all the way to just east of Pt. Conception, forming a strong front there. In Case 1, the corresponding front is in the central basin (northwest side of the tight cyclone), while there is cold water near the east end of the channel because of the north rim upwelling jet. Thus, at least from water mass characteristics along the northern part of the SBC, Case 1 as a weak "flood west". The difference is only rather subtle details in local wind forcing. The model "flood east" is mainly from cold upwelled water propagating eastward along the north

rim of the SBC. A wind switch from the prevailing northwest to straight west or southwest (blocked by the north SBC shore mountains) may rapidly cool the north side of the SBC by augmenting the wind-forced upwelling.

In summary, surface Ekman layer flows and associated upwelling suggest that it may be necessary to accurately specify local wind forcing as well as the Davidson Current and other external effects in order to forecast the SBC beyond a few days. Direct local vorticity generation by local wind curl may be secondary. Our SBC-demonstrated nesting technology has great potential for detailed coastal nowcast/forecast systems.

IMPACT/IMPLICATIONS

A major impact of this research is that we now have a working one minute (approximately two kilometer) horizontal resolution, 20-vertical level, SBC Model that shows extremely detailed flow features and local wind sensitivity.

In conjunction with researchers at NPS, we also have a five minute resolution CC model with which we are implementing full two-way nesting with our SBC model.

Ultimately, there will be triple nesting with a Pacific or global scale model, with data assimilation. Because the above results demonstrate realistic DieCAST model performance even without data assimilation, we expect that low-cost assimilation approaches such as simple nudging will keep the model on track with nature and thus yield an excellent nowcast/forecast capability.

The SBC model runs about one model week per cpu-hour on a Silicon Graphics Indigo 2 workstation. On a newer Pentium Pro PC, the SBC model will run more than one month per cpu day. The DieCAST model has thus been shown to have great potential for high resolution shipboard coastal forecast applications.

TRANSITIONS

In FY98 and with continued ONR funding for this project, the plan is to deliver a high resolution SBC Model nested in our California Current model with data assimilation, with the results submitted to a refereed journal. Our long term goal is to deliver a prototype nowcast/forecast system for the SBC.

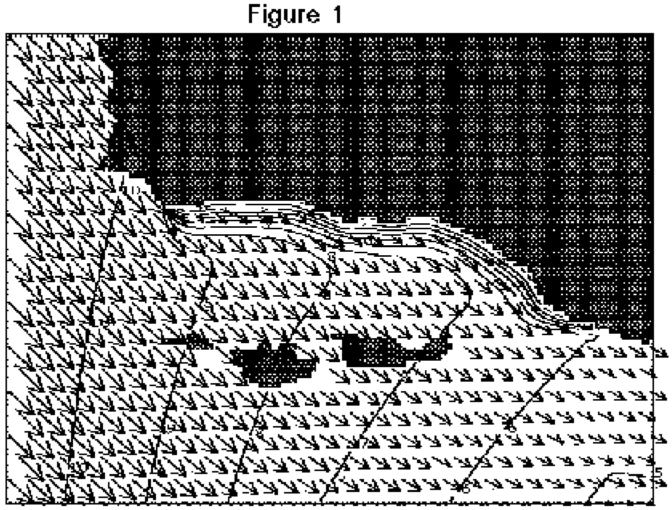
RELATED PROJECTS

This project is being directly leveraged by the FY97 ONR Research Grant N00014-97-1-0099 to CAST for Modeling with Data Assimilation in the North Atlantic (DAMEE).

This project is also being significantly leveraged by other ongoing research efforts, both nationally and internationally. For example, Texas A & M University and NRL Stennis are collaborating for general modeling of the Gulf of Mexico using DieCAST, the University of Auckland has adapted DieCAST and its new numerics as the New Zealand Regional Model, the New Zealand Electric Company uses DieCAST for the high resolution Doubtful Sound Model, Dalhousie University is working on adding data assimilation to the DieCAST version in the Gulf of St. Lawrence and Grand Banks Region, NRL Stennis is using DieCAST for high resolution modeling of Adriatic Sea nested within a 1/8 degree Mediterranean Sea DieCAST model and for coupled Ice-Sea Modeling in the Arctic, Bedford Institute of Oceanography is investigating DieCAST performance

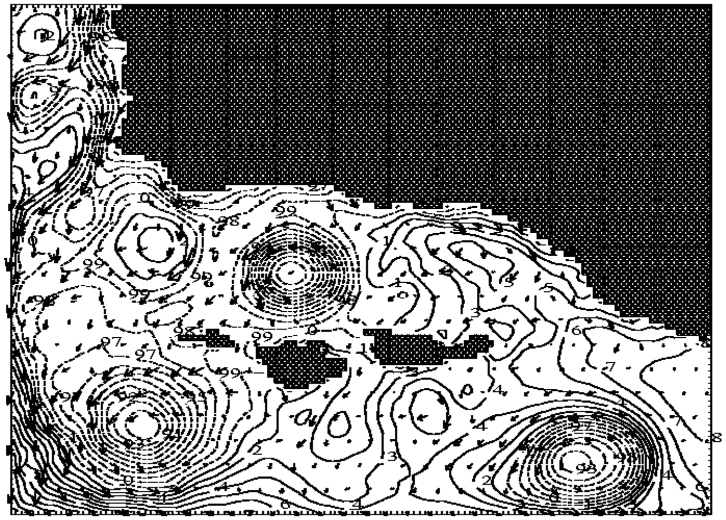
in coastal zones and in the North Atlantic, NOAA National Marine Fisheries Service has used DieCAST in the Gulf of Mexico to study algal blooms, University of New South Wales, Sydney, Australia is using DieCAST to run simulations for the East Australian Current and Tasman Sea, Australian Defense Forces Academy is running simulations in the Hawaiian Island area using DieCAST, NOAA Great Lakes Environmental Research Laboratory has configured DieCAST to run simulations in Lakes Erie and Michigan, Memorial University is using DieCAST for simulations in Newfoundland Bay, Florida State University has coupled DieCAST to an atmospheric model to investigate hurricane response, MIT and Canadian Meteorological Center have coupled DieCAST to the Canadian operational meteorological model, and Oregon State University is developing high resolution Southern Hemisphere and global scale versions of the DieCAST Ocean Model. Some other collaborations involve James Cook University, University of Trieste in Italy, UIB at Palma in Spain, Government of Bulgaria, University of Otago and Leigh Laboratory in New Zealand, and CSIRO in Australia.

Figure 1

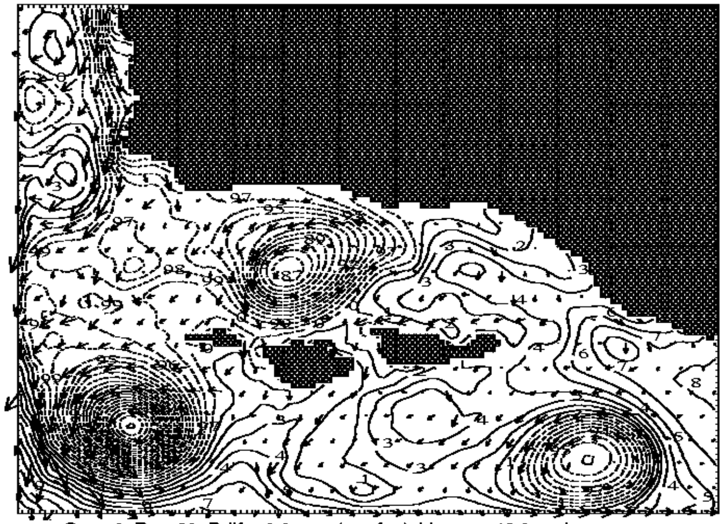


Modified Hellerman Winds (with mountain shadow effect) used in Case 2.

Figure 2

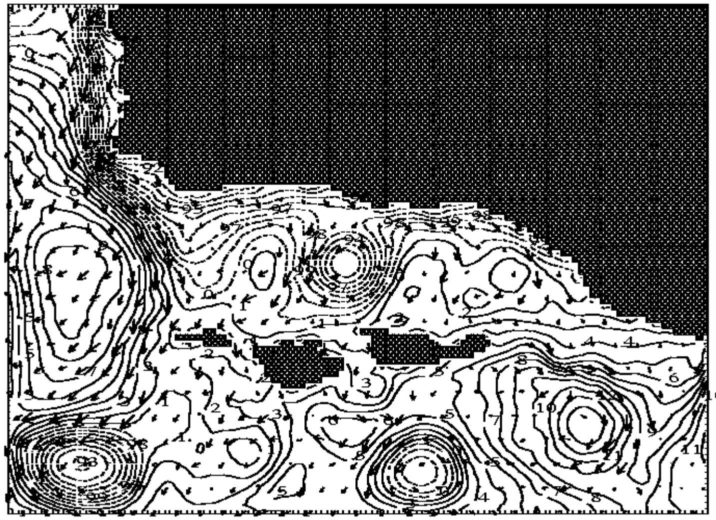


Case 1: Day 30, Pdif = 4.9 cms (eq. fsa), Vmax = 47.8 cm/sec

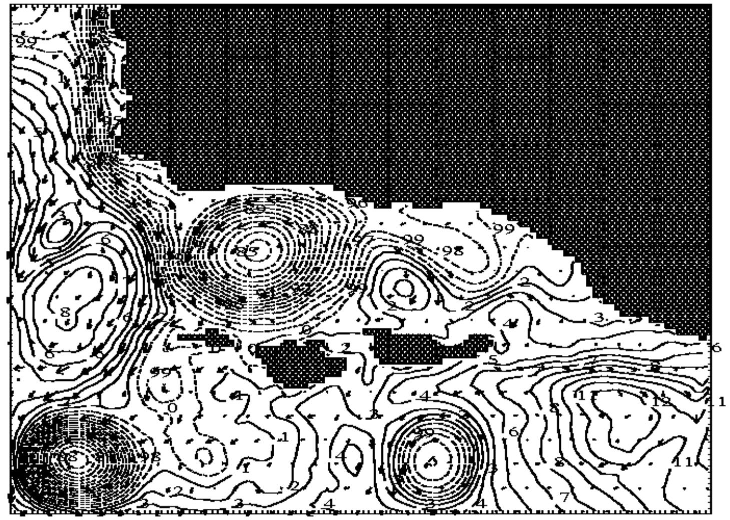


Case 2: Day 30, Pdif = 6.6 cms (eq. fsa), Vmax = 43.6 cm/sec

Figure 3



Case 1: Day 60, Pdif = 5.6 cms (eq. fsa), Vmax = 45.5 cm/sec



Case 2: Day 60, Pdif = 5.9 cms (eq. fsa), Vmax = 50.6 cm/sec